

- 2** • At time  $t = 0$ , a particle with charge  $q = 12 \mu\text{C}$  is located at  $x = 0$ ,  $y = 2 \text{ m}$ ; its velocity at that time is  $\mathbf{v} = 30 \text{ m/s } \mathbf{i}$ . Find the magnetic field at (a) the origin; (b)  $x = 0$ ,  $y = 1 \text{ m}$ ; (c)  $x = 0$ ,  $y = 3 \text{ m}$ ; and (d)  $x = 0$ ,  $y = 4 \text{ m}$ .
- 3** • For the particle in Problem 2, find the magnetic field at (a)  $x = 1 \text{ m}$ ,  $y = 3 \text{ m}$ ; (b)  $x = 2 \text{ m}$ ,  $y = 2 \text{ m}$ ; and (c)  $x = 2 \text{ m}$ ,  $y = 3 \text{ m}$ .
- 10** • A small current element  $I d\vec{\ell}$ , with  $d\vec{\ell} = 2 \text{ mm } \hat{\mathbf{k}}$  and  $I = 2 \text{ A}$  is located at the origin. Find the magnitude of  $d\vec{\mathbf{B}}$  and indicate its direction on a diagram at (a)  $x = 2 \text{ m}$ ,  $y = 4 \text{ m}$ ,  $z = 0$  and (b)  $x = 2 \text{ m}$ ,  $y = 0$ ,  $z = 4 \text{ m}$ .

- 15 ••** A single-turn circular loop of radius 8.5 cm is to produce a field at its center that will just cancel the earth's field of magnitude 0.7 G directed at  $70^\circ$  below the horizontal north direction. Find the current in the loop and make a sketch showing the orientation of the loop and the current.
- 18 •••** Two coils, each with  $N$  turns, are separated by a distance equal to their radius  $R$  and that carry equal currents  $I$  such that their axial fields add are called Helmholtz coils. A feature of Helmholtz coils is that the resultant magnetic field  $B$  between the coils is very uniform. One coil is in the  $yz$  plane with its center at the origin and the other is in a parallel plane at  $x = R$ . Show that at the midpoint of the coils ( $x = \frac{1}{2}R$ )  $dB_x / dx = 0$ ,  $d^2B_x / dx^2 = 0$ , and  $d^3B_x / dx^3 = 0$ . This shows that the magnetic field at points near the midpoint is approximately equal to that at the midpoint. Explain.

- 19 •** Two wires lie in the plane of the paper and carry equal currents in opposite directions, as shown. At a point midway between the wires, the magnetic field is (a) zero. (b) into the page. (c) out of the page. (d) toward the top or bottom of the page. (e) toward one of the two wires.



- 20 •** Two parallel wires carry currents  $I_1$  and  $I_2 = 2I_1$  in the same direction. The forces  $F_1$  and  $F_2$  on the wires are related by (a)  $F_1 = F_2$ . (b)  $F_1 = 2F_2$ . (c)  $2F_1 = F_2$ . (d)  $F_1 = 4F_2$ . (e)  $4F_1 = F_2$ .

- 21\* •** A wire carries an electrical current straight up. What is the direction of the magnetic field due to the wire a distance of 2 m north of the wire? (a) North (b) East (c) West (d) South (e) Upward

Problems 24 to 29 refer to Figure 29-39, which shows two long, straight wires in the  $xy$  plane and parallel to the  $x$  axis. One wire is at  $y = -6$  cm and the other is at  $y = +6$  cm. The current in each wire is 20 A.

- 24 •** If the currents in Figure 29-39 are in the negative  $x$  direction, find  $\mathbf{B}$  at the points on the  $y$  axis at (a)  $y = -3$  cm, (b)  $y = 0$ , (c)  $y = +3$  cm, and (d)  $y = +9$  cm.

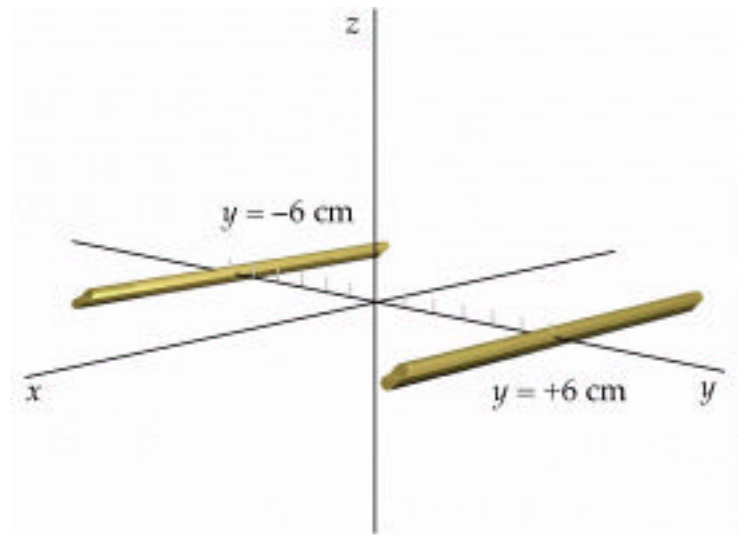
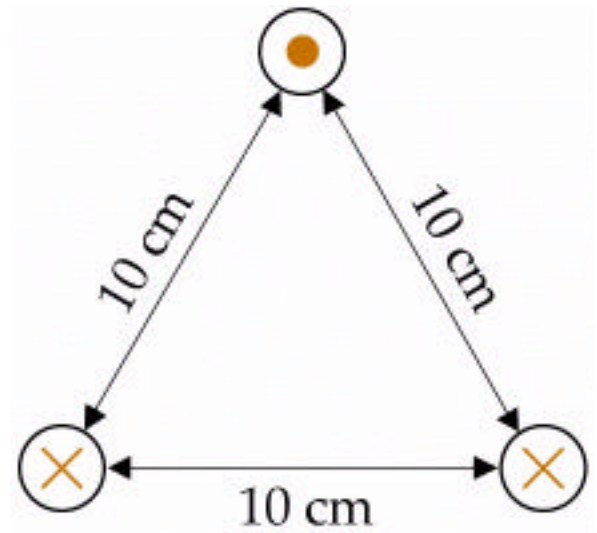


Figure 29-39

- 26 • Find  $B$  at points on the  $y$  axis as in Problem 24 when the current in the wire at  $y = -6$  cm is in the negative  $x$  direction and the current in the wire at  $y = +6$  cm is in the positive  $x$  direction.

- 29\* • Find the magnitude of the force per unit length exerted by one wire on the other.

- 33\* • Three long, parallel, straight wires pass through the corners of an equilateral triangle of sides 10 cm as shown, where a dot means that the current is out of the paper and a cross means that it is into the paper. If each current is 15.0 A, find (a) the magnetic field  $B$  at the upper wire due to the two lower wires, and (b) the force per unit length on the upper wire.



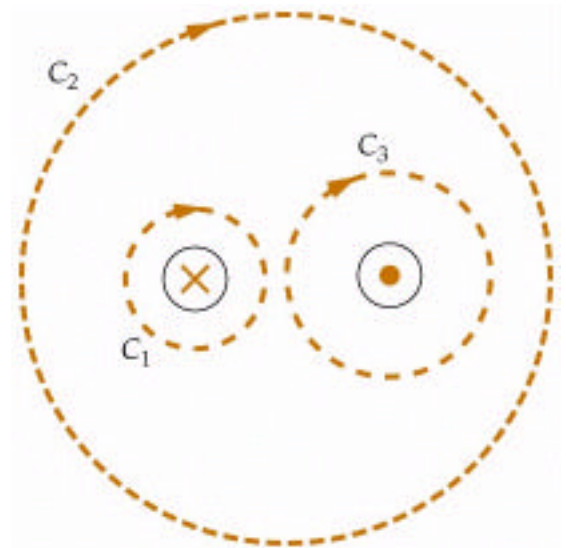
**34 ••** Work Problem 33 with the current in the lower right corner of the figure reversed.

**40 •** A solenoid with length 30 cm, radius 1.2 cm, and 300 turns carries a current of 2.6 A. Find  $B$  on the axis of the solenoid ( $a$ ) at the center, ( $b$ ) inside the solenoid at a point 10 cm from one end, and ( $c$ ) at one end.

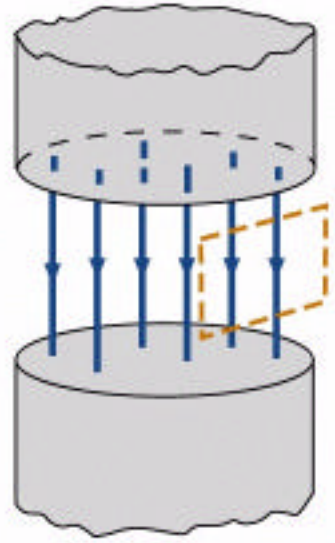
- 42 •••** A solenoid has  $n$  turns per unit length and radius  $R$  and carries a current  $I$ . Its axis is along the  $x$  axis with one end at  $x = +\frac{1}{2}\ell$  and the other end at  $x = -\frac{1}{2}\ell$ , where  $\ell$  is the total length of the solenoid. Show that the magnetic field  $B$  at a point on the axis outside the solenoid is given by

$$B = \frac{1}{2} \mu_0 n (\cos \theta_1 - \cos \theta_2), \text{ where } \cos \theta_1 = \frac{x + \frac{1}{2}\ell}{[R^2 + (x + \frac{1}{2}\ell)^2]^{1/2}} \text{ and } \cos \theta_2 = \frac{x - \frac{1}{2}\ell}{[R^2 + (x - \frac{1}{2}\ell)^2]^{1/2}}$$

- 47 •** In the figure, one current is 8 A into the paper, the other current is 8 A out of the paper, and each curve is a circular path. (a) Find  $\oint_C \vec{B} \cdot d\vec{\ell}$  for each path indicated. (b) Which path, if any, can be used to find  $B$  at some point due to these currents?

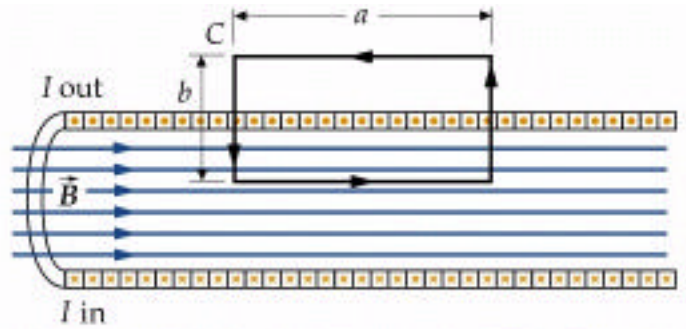


- 50 ••** Show that a uniform magnetic field with no fringing field, such as that shown, is impossible because it violates Ampère's law. Do this by applying Ampère's law to the rectangular curve shown by the dashed lines.



- 52 ••** An infinitely long, thick, cylindrical shell of inner radius  $a$  and outer radius  $b$  carries a current  $I$  uniformly distributed across a cross section of the shell. Find the magnetic field for (a)  $r < a$ , (b)  $a < r < b$ , and (c)  $r > b$ .

- 53\* ••** The figure shows a solenoid carrying a current  $I$  with  $n$  turns per unit length. Apply Ampère's law to the rectangular curve shown to derive an expression for  $B$  assuming that it is uniform inside the solenoid and zero outside it.



- 54 ••** A tightly wound toroid of inner radius 1 cm and outer radius 2 cm has 1000 turns of wire and carries a current of 1.5 A. (a) What is the magnetic field at a distance of 1.1 cm from the center? (b) What is the field 1.5 cm from the center?

- 56 •** True or false:

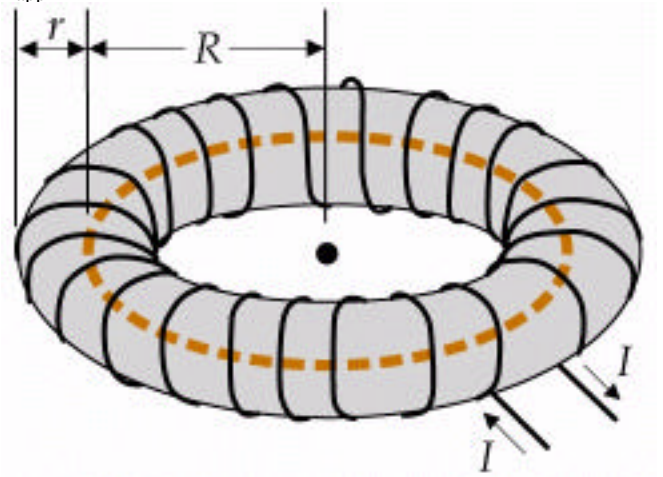
- (a) Diamagnetism is the result of induced magnetic dipole moments.  
 (b) Paramagnetism is the result of the partial alignment of permanent magnetic dipole moments.

- 57\*** • If the magnetic susceptibility is positive,
- (a) paramagnetic effects or ferromagnetic effects must be greater than diamagnetic effects.
  - (b) diamagnetic effects must be greater than paramagnetic effects.
  - (c) diamagnetic effects must be greater than ferromagnetic effects.
  - (d) ferromagnetic effects must be greater than paramagnetic effects.
  - (e) paramagnetic effects must be greater than ferromagnetic effects.
- 59** • Which of the four gases listed in Table 29-1 are diamagnetic and which are paramagnetic?
- 60** • A tightly wound aluminum-core solenoid 20 cm long has 400 turns and carries a current of 4 A such that its axial field is in the  $z$  direction. Find  $B_{\text{app}}$ ,  $M$ , and  $B$  at the center, neglecting end effects.
- 64** • A long solenoid carrying a current of 10 A has 50 turns/cm. What is the magnetic field in the interior of the solenoid when the interior is (a) a vacuum, (b) filled with aluminum, and (c) filled with silver?

**69\* ••** Nickel has a density of  $8.7 \text{ g/cm}^3$  and molecular mass of  $58.7 \text{ g/mol}$ . Its saturation magnetization is given by  $\mu_0 M_s = 0.61 \text{ T}$ . Calculate the magnetic moment of a nickel atom in Bohr magnetons.

**71 •** Show that Curie's law predicts that the magnetic susceptibility of a paramagnetic substance is  $\chi_m = \mu\mu_0 M_s / 3kT$ .

- 74 •• A toroid with  $N$  turns carrying a current  $I$  has mean radius  $R$  and cross-sectional radius  $r$ , as shown, where  $r \ll R$ . When the toroid is filled with material, it is called a *Rowland ring*. Find  $B_{\text{app}}$  and  $B$  in such a ring, assuming a magnetization  $\mathbf{M}$  everywhere parallel to  $\mathbf{B}_{\text{app}}$ .



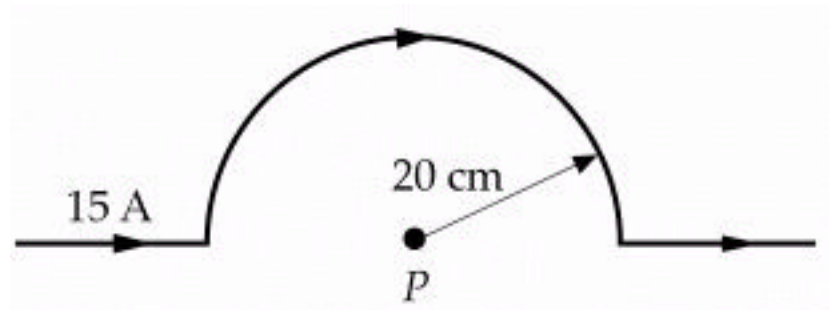
- 77\* • For annealed iron, the relative permeability  $K_m$  has its maximum value of about 5500 at  $B_{\text{app}} = 1.57 \times 10^{-4}$  T. Find  $M$  and  $B$  when  $K_m$  is maximum.

- 80 ••** A long solenoid with 50 turns/cm carries a current of 2 A. The solenoid is filled with iron, and  $B$  is measured to be 1.72 T. (a) Neglecting end effects, what is  $B_{\text{app}}$ ? (b) What is  $M$ ? (c) What is the relative permeability  $K_m$ ?
- 87 •** True or false:
- (a) The magnetic field due to a current element is parallel to the current element.
  - (b) The magnetic field due to a current element varies inversely with the square of the distance from the element.
  - (c) The magnetic field due to a long wire varies inversely with the square of the distance from the wire.
  - (d) Ampère's law is valid only if there is a high degree of symmetry.
  - (e) Ampère's law is valid only for continuous currents.
- 88 •** Can a particle have angular momentum and not have a magnetic moment? Explain.
- 90 •** A circular loop of wire carries a current  $I$ . Is there angular momentum associated with the magnetic moment of the loop? If so, why is it not noticed?

- 92 • When a current is passed through the wire shown, will it tend to bunch up or form a circle?



- 93\* • Find the magnetic field at point  $P$  in figure shown.



- 100 ••** The closed loop shown in Figure 29-53 carries a current of 8.0 A in the counterclockwise direction. The radius of the outer arc is 60 cm, that of the inner arc is 40 cm. Find the magnetic field at point  $P$ .

